FINAL SYNOPSIS OF THE PH. D THESIS

"EFFECT OF YOGA ON GUT MICROBIOTA INFLUENCED IMMUNOMODULATORY FUNCTIONS IN OBESE INDIVIDUALS"

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IN
YOGIC SCIENCE

By

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Effect of Yoga on Gut Microbiota-Influenced Immunomodulatory Functions in Obese Individuals

Chapter 1

Introduction:

There has been an intense escalation in the occurrence of obesity at an alarming rate in India and other South Asian countries (Chopra et al., 2004; Prasad et al., 2012; Nicolucci et al., 2017). Physical inactivity combined with unhealthy dietary practices has been identified as a significant risk factor for a large number of health complications in obese individuals and also have a higher susceptibility to developing metabolic disorders during their lifetime (Bentham et al., 2017). Many pieces of evidence corroborate the importance of gut microbial homeostasis in metabolic disorders linked to obesity and liver diseases (Bashiardes et al., 2016; Ma et al., 2017).

Purpose and Importance of the Study

The rationale of the proposed study is that environmental stimuli, behavioral practices, and physical activity status in humans can significantly contribute to the immune-regulating capacity of the gut microbiome throughout the lifespan. Exercise-induced changes in the gut microbiota have been correlated with changes in host physiology, including alterations in metabolism, immunity, and behavior. Yoga is an ancient form of mind-body fitness that integrates physical, mental, and spiritual practices to improve human health. Several studies have reported improved physiological, physical, and psychological functions following yoga.

Conclusion

This study addresses the pressing issue of rising obesity rates, emphasizing the critical link between lifestyle factors and metabolic disorders. Focusing on the interplay of gut microbiome and immune regulation, it explores how practices like yoga can positively impact physical, mental, and metabolic health. The findings underscore the importance of holistic approaches to combatting the complex challenges posed by obesity.

Aim and Objective of Research

The rationale of the proposed study is that environmental stimuli, behavioral practices, and physical activity status in humans can significantly contribute to the metabolic and immune-regulating capacity of the gut microbiome throughout the lifespan. Exercise-induced changes in the gut microbiota have been correlated with changes in host physiology, including alterations in metabolism, immunity, and behavior. Yoga is an ancient form of mind-body fitness that integrates physical, mental, and spiritual practices to improve human health. Several studies have reported improved physiological, physical, and psychological functions following yoga. Thus, we aim for the practice of yoga to have a beneficial effect on the immune-regulating capacity of the gut microbiome in obese individuals by positively modulating them. The key questions expected to be answered by the proposed research are:

i. Does the yoga practice have any influence (can modulate) on the composition and diversity of gut microbiota in obese individuals?

ii. Whether the practice of yoga have any beneficial effect on the enhancement of gut-microbiota-influenced immune-modulatory functions in obese individuals?

Specific Aim and Objectives of the Study

Aim: of the study:

The purpose of the study is to determine the effect of yoga on gut Microbiome and immunomodulatory functional change due to the diversity of gut Microbiome in obese individuals.

Objectives of the study:

- To study the effect of yoga practice on the composition and diversity of gut microbiota in obese individuals
- To elucidate the influence of yoga practice on the enhancement of gut-microbiota-influenced immunomodulatory function

Subject selection criteria:

Inclusion Criteria

Study subjects healthy obese (n=23) were divided into two arms Intervention and control based on Body Mass Index (BMI). [Obese if their BMI is 25.0 kg/m2 or above]. All Males and Females who fulfill the inclusion criteria were included.

Exclusion Criteria

Subjects/Participants with pregnancy, lactating, cardiovascular disease, liver and kidney

function impairment, HCV, HIV, HBsAg seropositive status, patients with known gastrointestinal bleeding, psychologically ill, and under 18 years of age were excluded from the study.

Hypothesis:

The practice of yoga has a significant beneficial effect on the immune-regulating capacity of the gut microbiome in obese individuals by positively modulating them.

Null Hypothesis: There will not be significant changes in the diversity of the gut microbiome and its modulation influences immune functions before and after the yoga practice in obese.

The Purpose Study:

In the present scenario, humans are under threat from many chronic diseases, lifestyle disorders, non-communicable diseases, etc. A major cause of all these diseases was found to be improper lifestyle and stress. Excessive stress is known to cause hormonal and chemical imbalances in the human body. Yoga has been practiced in India since the Vedic period and was coordinated and organized systematically. There are many written descriptions and classical evidence of the beneficial effects of yoga on digestion and metabolism. However, limited scientific evidence is accessible regarding the impact of yoga practice on gut microbiota and improvement in metabolic status. The main purpose of the proposed research is to decode the benefits of yoga and meditation on the composition and diversity of gut microbiota in obese individuals, as well as a beneficial effect on the enhancement of gut-microbiota, influenced immune-modulatory functions in them. The results obtained through this study would justify the beneficial classical references with modern scientific evidence.

Chapter – 2

Overview of Obesity

Obesity is a prevalent and significant global health issue characterized by excess body fat accumulation. It results from an imbalance between caloric intake and energy expenditure, leading to weight gain. Obesity increases the risk of various chronic health conditions, including cardiovascular diseases, type 2 diabetes, and certain types of cancer. It also has implications for mental health and overall well-being. The causes of obesity are multifactorial, involving genetic, environmental, and lifestyle factors. Unhealthy dietary habits, sedentary lifestyles, genetic predisposition, and socioeconomic factors all contribute to the development of obesity. The rise of obesity is a concerning trend worldwide, affecting people of all ages, genders, and backgrounds.

Managing obesity requires a comprehensive approach, including lifestyle modifications, behavioral changes, and, in some cases, medical interventions. Encouraging regular physical activity, adopting a balanced diet, and promoting healthier environments are essential components of obesity prevention and management. Obesity has become a public health challenge, with significant social and economic consequences. Addressing this epidemic requires collaborative efforts from healthcare providers, policymakers, communities, and individuals to implement effective prevention strategies and support those affected by obesity in achieving better health outcomes.

Modern Concept of Obesity

Obesity is a complex and multifactorial medical condition characterized by an excess accumulation of body fat that can have negative effects on health. It is a significant global public health issue, as its prevalence has steadily increased in many countries over the past few decades. Here is an overview of obesity, including its causes, health implications, and management:

Causes and Risk Factors:

Unhealthy Diet: Consuming a diet high in calories, saturated fats, sugars, and processed foods can contribute to weight gain and obesity.

Sedentary Lifestyle: Lack of physical activity and a sedentary lifestyle can lead to an imbalance between calorie intake and expenditure, resulting in weight gain.

Genetic Factors: Genetic predisposition can influence an individual's susceptibility to obesity. Environmental Factors: Environmental factors, such as easy access to high-calorie foods,

urbanization, and changes in food systems, can contribute to obesity.

Socioeconomic Factors: Socioeconomic status can also influence the prevalence of obesity, with lower-income individuals facing higher risks due to limited access to healthier food options and recreational facilities.

Health Implications:

Cardiovascular Diseases: Obesity is a major risk factor for heart diseases, including hypertension, coronary artery disease, and stroke.

Type 2 Diabetes: Obesity increases the risk of developing insulin resistance and type 2 diabetes.

Metabolic Syndrome: Obesity is associated with metabolic abnormalities, such as high blood pressure, elevated blood sugar, and abnormal lipid levels.

Respiratory Disorders: Obesity can lead to respiratory issues, including sleep apnea and obesity hypoventilation syndrome.

Musculoskeletal Problems: Excess body weight can put a strain on the joints and lead to conditions like osteoarthritis.

Mental Health: Obesity is linked to a higher risk of depression, anxiety, and low self-esteem.

Management:

Lifestyle Changes: Adopting a balanced and nutritious diet, increasing physical activity, and maintaining a healthy lifestyle are essential for weight management.

Behavioral Therapy: Cognitive-behavioral approaches can help individuals modify eating habits, increase physical activity, and address emotional factors related to overeating.

Medical Interventions: In some cases, medical treatments, such as prescription medications or weight-loss surgeries, may be recommended for severe obesity and when lifestyle changes alone are not sufficient.

Support and Counseling: Support groups and counseling can be valuable for individuals seeking to manage obesity and make sustainable lifestyle changes.

Prevention:

Preventing obesity involves promoting healthy eating habits, encouraging regular physical activity, and creating environments that support healthy behaviors. Public health initiatives, educational programs, and policy changes play a crucial role in addressing the obesity epidemic.

In conclusion, obesity is a complex condition influenced by a combination of genetic, behavioral, environmental, and socioeconomic factors. Addressing obesity requires a comprehensive approach that includes lifestyle changes, behavioral interventions, medical

treatments when necessary, and efforts to create a supportive environment for healthy living.

Indian and Yogic Concept of Obesity

Among the six ancient philosophies, Yoga has been recognized as one of the most important as it included in day-to-day life since the ancient period. From the period of Veda, Upanishad, Vedanga, Ayurveda, Bhagavadgeetha, and in Yogic texts there are some references about various disorders, their symptoms, and practices to overcome the disorder are explained.

When we see the Upanishads in Taittariya Upanishad concept of Kosha is explained. In this the five-sheath concept Annamaya, Pranamaya, Manomaya, Vijnanamaya, and anandamaya koshas if we consider the changes of a person in Obesity it can be correlated with three layers especially the changes in the physical body (Annamaya kosha) due to imbalance of prana and the imbalance of pranamaya kosha will be because of the disturbance in Manomaya kosha grossly connected with mind. According to Yoga Vasista, *Manh prashamanopayaha yoga ithyabhidhiyate (Yoga Vasistha 3.9.32)* Yoga is a skillful way to calm down the mind. As obesity has a great relationship with disturbed thoughts or stress, yoga will be a better way to control the mind.

In Svetasvatara Upanisad(Lokeśvarānanda, 1994) while explaining the quality of a succeeded yogi;

Laghutvamarogyamalolupatvam Varnaprasädam svarasaushtavanca | Gandhah shubho

mütraparishamalpam Yogapravruttim prathamam vadanti|| Svetasvatara Upanisad- 2-13

A sign of success in yoga is, that the yogi will have the lightness of the body (lagutvam), good health (ärogyam), bright complexion *(*Varnaaprasädaà), sweet voice (svarasaushtava), and good fragrance (Gandhah) of the body. Here it has mentioned the Laghutvam in terms of lightness of the body, so the practice of yoga can decrease overweight to attain lightness. Even in ancient scriptures as an explanation of eight Siddhis,

Anima mahima caiva laghima garima tatha I
Prapthi prakamyamishatvam vashitvam cashta siddhayah II

One out of these eight siddhis Laghimā refers to the ability to become weightless or lighter which can be correlated with the lightness of the body or reduction of body weight in terms of obesity.

According to the Indian medicine system, Ayurveda the features, causes, symptoms, and treatment options for obesity are well defined. According to Ayurveda all digestive and metabolic functions are based on Agni and levels of jatharagni and dhatvagni are the reason the cause of diseases, especially the dysfunction of dhatvagni is responsible for obesity (Sthoulya)(Dr Gopalini Ajay G & Dr Sarmandal A Bhushan, 2007). In the same narration(Dr Gopalini Ajay G & Dr Sarmandal A Bhushan, 2007) Obesity is classified as per different acharyas, Acharya caraka has classified into Sthula and athisthula, according to vagbhata Adhika, Madhya, and Hina, as per acharya sushrutha Sthoulya and medodara.

One of the Ayurveda Text Book of SWASTHAVRITTA (Sushant Sukumar & Shashirekha, 2019) explains the symptoms, features, and etiology of obesity according to classical Ayurveda texts as follows;
Iha khalu sariramadhikrutyashtau purushah nindita bhavanti |
Tadyathä atidirghasca atihrasvasca atilomä ca alomä ca atikrshnasca atigaurasca atisthulasca atikrshasceti | Caraka Samhita sutrasthana 1-12-3

Depending on the physical appearance there are 8 types of undesirables (Nindita purusha) persons- too tall, too short, too hairy, hairless, too dark, too white, too fat, and too lean.

In summary, the Indian and Yogic concept of obesity is rooted in a holistic understanding of health that includes the physical, mental, emotional, and spiritual aspects of an individual. It offers a comprehensive approach to managing obesity through lifestyle changes, dietary modifications, mind-body practices, and embracing a deeper sense of self-awareness and connection.

Chapter – 3

Review of Literature

Research evidence suggests that there is a relationship between gut microbiota and obesity in humans. In obese it is found that individuals with a low bacterial richness (23% of the population) are characterized by more marked overall adiposity, insulin resistance, and dyslipidemia and a more pronounced inflammatory phenotype and variation in the gut microbiome identify an increased risk of progressing to adiposity-associated co-morbidities(Le Chatelier, et al., 2013).

Recent research on gut microbiome emerged with the concept of a host and its microbiota composed of holobiont regulated several physiological functions including immune system function, metabolism, and nervous system functioning. Its interplay with the local Microbiome, intestinal epithelium, and immune cells emerged to support gastrointestinal homeostasis. The manipulation of microbiota supports the evidence role of the microbiota in immune homeostasis (Sekirov, et al., 2008).

Both innate and adaptive immune functions together help to generate protective immunity in humans. As per the research evidence, immune cells play a major role in causing some chronic diseases, and obesity may impair the ability to mount a protective immune response and increase complications of infection(Sheridan, et al., 2012)(Hemalatha Rajkumar, 2013).

In support of the evidence one of the Narrative Review of Yoga Intervention Clinical Trials Including Weight-Related Outcomes defines that therapeutic yoga programs are frequently effective in promoting weight loss and/or improvements in body composition with key features like frequency of practice, longer intervention duration, a yogic dietary component, residential component, and home-practice component suggests that yoga can be an appropriate and potentially successful intervention for weight maintenance, prevention of obesity, and risk reduction for diseases in which obesity plays a significant causal role(Rioux Grace Jennifer & Ritenbaugh Cheryl, 2013).

One of the recent systematic reviews of randomized controlled trials on Yoga and immune system functioning comparing Fifteen RCTs suggests that yoga can down-regulate pro-inflammatory markers and in particular decreases in IL-1beta, as well as indications for reductions in IL-6 and TNF-alpha were found suggesting yoga can be implemented as a complementary intervention for populations at risk or already suffering from diseases with an inflammatory component(Falkenberg, Eising, & Peters, 2018).

One of the researches on athletes suggests that exercise has an impact on gut microbiota

diversity compared to sedentary subjects (Clarke, et al., 2014). In the same study explaining the high diversity of gut microorganisms, athletes had fewer Bacteroidetes and relative abundance in the firmicutes, Ruminococcaceae, S24-7, Succinivibrionaceae, RC9 gut, and Succinivibrio groups (Clarke, et al., 2014).

The research evidence suggests that exercise has a positive impact on gut diversity and is related to immunomodulatory functions. As yoga has a positive impact on physiological functions when compared with exercise in different aspects like changes in the muscular system, impact on the respiratory system, immune system, stress level, etc., and also with some evidence which supports that yoga has an effect on immune system function like the short term studies on yoga proves that it can be beneficial in markers of inflammation and endothelial function in overweight and obese men revealing that reduction in plasma IL-6 and increase in the plasma adiponectin (Sarvottam, et al., 2013) can create a research question that the diversity of gut can be altered positively by the practice of yoga and even it can have a positive impact on immunomodulatory functions especially in obese.

With much evidence that supports clinical trials and Meta-analysis, we can assume that yoga is a personalized holistic approach to improving metabolism, immune function, and overall health. With a holistic approach, yoga can be beneficial in improving physiological functions, psychological functions and thereby improve the psychophysiological health of an individual. As few classical beneficial references in yogic and Indian texts support this aspect and modern scientific evidence, we can assume that Yoga practice influences the composition and diversity of gut microbiota in obese individuals as well as the beneficial effect on the enhancement of gut-microbiota influenced immune-modulatory functions in them. This can justify the effect of yoga explained in classical references scientifically.

Chapter – 4

Material and Methods

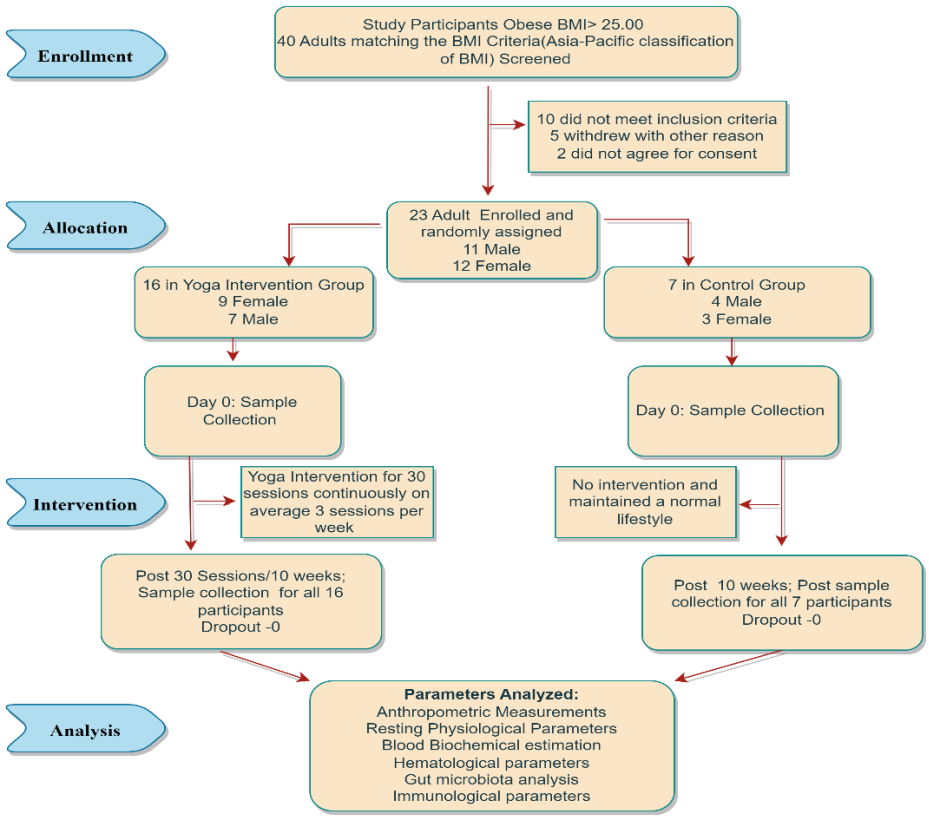
The study was conducted at the Department of Human Consciousness & Yogic Sciences, Mangalore University in collaboration with Nitte University Centre for Science Education and Research, Mangalore. The study participants were recruited based on body mass Index which is the criteria to identify obese individuals [Obese if their BMI is 25.0Kg/m2 or above as per the Asian Pacific Classification of Obesity]. In this study research, we undertook a two-arm study with a total number sample size of 23 divided into the experimental (Oy-yoga practice/intervention) (n=16) and control group (Oc-non-yoga control group) (n=07). Both groups matched for weight, age, and BMI.

Participants were recruited through the therapy center at Mangalore University and local advertisements. People interested in participating underwent a telephone interview with study details and were invited for a medical examination. The medical examination included a detailed case taking with a physical examination and a review of medical and medication histories. Suitable participants (as per predefined criteria) were provided with comprehensive written and verbal information about the study, and written consent was obtained from these people before their inclusion in the trial.

Study Design:

The study was designed as a single-center, simple random sampling with a two-arm design. A total of 40 people were screened for obesity between March 2021 and December 2022, 23 (males = 11, females = 12) of whom were included and randomized into the Oy-Obese Yoga Group (n = 16) and Oc -Obese Control Group (n =7). The demographic components like age, sex, education, physical activity, food habits, anthropometric parameters like height, weight, body mass index, waist circumference, hip circumference, waist-hip ratio, and other physiological parameters like systolic and diastolic blood pressure were comparable between the two intervention groups at the beginning of the study.

Fig 1: Study flow diagram


Enrollment
Study Participants Obese BMI> 25.00
40 Adults matching the BMI Criteria(Asia-Pacific classification of BMI) Screened
10 did not meet inclusion criteria
5 withdrew with other reason
2 did not agree for consent
Allocation
23 Adult Enrolled and randomly assigned
11 Male
12 Female
16 in Yoga Intervention Group
9 Female
7 Male
7 in Control Group
4 Male
3 Female
Day 0: Sample Collection
Day 0: Sample Collection
Intervention
Yoga Intervention for 30 sessions continuously on average 3 sessions per week
No intervention and maintained a normal lifestyle
Post 30 Sessions/10 weeks; Sample collection for all 16 participants
Dropout -0
Post 10 weeks; Post sample collection for all 7 participants
Dropout -0
Analysis
Parameters Analyzed:
Anthropometric Measurements
Resting Physiological Parameters
Blood Biochemical estimation
Hematological parameters
Gut microbiota analysis
Immunological parameters

Study Approval:

Before patient recruitment, the study received approval from the Institutes of Human Ethical Committee of Mangalore University.

Approval File No: MU-IHEC-2021-2

The trial was registered with ClinicalTrials.gov under the registration number

CTRI Reg No: CTRI/2022/01/039337

Sample Size

The total sample for the study is 23 (Experimental Group 16+ Control Group 07)

Validation of Protocol and Intervention Details

In the pursuit of validating the yoga module designed for the study "Effect of Yoga on Gut Microbiota Influenced Immunomodulatory Functions in Obese Individuals," a rigorous process was undertaken. Experts in the field of yoga were invited to review the module's structure, content, and applicability. Through a comprehensive assessment facilitated by a "scoring sheet" and "Yoga Performance Assessment" documents, their invaluable insights were gathered. These assessments played a pivotal role in refining and validating the yoga module, ensuring its relevance and effectiveness in clinical practice. Accompanying documents outlining the aim

and objectives of the study, as well as classical references informing the module's development, were provided for the experts' reference. This collaborative effort underscores the interdisciplinary nature of the research and the commitment to advancing evidence-based interventions in the field of obesity management through yoga therapy.

Specific yoga module used for this study

S.No	Name of the Practice	No. of rounds/breathing	Target Symptoms
		Kriyas	
1	Kapalabhati	3	Stimulates the thymus gland
		Asanas	
2	Swastikasana	5	Calming Posture, Meditative Pose
3	Vajrasana	5	Overcomes Constipation, strengthens the lower body muscles
4	SuptaVajrasana	5	Massages the abdominal organs
5	Simhasana	5	Improves breathing capacity
6	Tadasana 1	5	Improves body posture and balance
7	Trikonasana	5	Stimulates function of abdominal organs
8	Parshvakonasana	5	Massages of Abdominal Organs increase peristaltic activity
9	Paschimottanasana	5	Improves digestion.
10	Purvottanasana	5	Counterpose for Paschimottanasana, strengthens core and back.
11	Janushirshasana	5	Stimulates the liver and kidneys
12	Pavanamuktasana	5	Strengthen the abdominal muscles, massage the intestines as well as stimulate the internal organs of the digestive system
13	Bhujangasana	5	Strengthens the spine, Stimulates abdominal organs
14	Shalabhasana	2	Helps relieve stress and strengthens the muscles of the spine, buttocks, and backs of the arms and legs.
15	Dhanurasana	1	It is effective in weight loss and improves blood circulation.
16	Vakrasana	5	Removes the stagnant, Increases the elasticity of the spine, and tones the spinal nerves.
17	Bharadwaja	5	Massages the abdominal organs
18	Ardhamatsyendrasana	5	Removes harmful stagnation in the digestive tract
19	Viparitakarani	2	Regulates blood flow, relieves stress and tension

20	Uttanapadasana	2	Improves the function of thyroid glands for healthy body metabolism.
Pranayamas			
21	Ujjayi	21	Clears phlegm & increases appetite.
22	Suryabhedana	21	Activates the body's functions.
23	AnulomaViloma	21	Manages blood circulation and decreases stress and anxiety.
24	Bhastrika	5-8	Oxygenates the blood increasing the vitality of all the organs and tissues.
25	Bhramari	21	Calming Effect on mind and body
Meditation/Relaxation			
26	OM Meditation	24	Gives peace, calm, tranquility, and serenity.
27	Yoga Nidra	Medium 1 round	Improves the functioning of the nervous system and endocrine system
Total Duration			**60 Min**

Parameters for the Data Collection

Anthropometric Measurements: Anthropometric measurements such as body weight, standing body height, body mass index (BMI), and Waist circumference of the study participants were taken with minimal clothing.

Resting Physiological Parameters: Brachial systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using the oscillometric method.

Analysis of blood biochemical estimation: Levels of fasting blood glucose, total cholesterol, and triglycerides were analyzed according to standard operating procedures using an automatic blood analyzer as part of the methodology.

Gut microbiota analysis: Diversity and composition of gut microbiota in obese individuals, and metagenomic analysis of the fecal samples were performed.

Analysis of immunological parameters: Levels of cytokines such as IL-6, IL-10, IL-1ra, IL-1β, and MCP-1 modulated due to yoga practice were assessed using commercially available ELISA kits. To eliminate inter-assay variance, all samples were analyzed in identical runs.

IgG N-glycan profile

In the study, glycan analysis was conducted utilizing the Dry Blood Spot (DBS) method, a technique renowned for its simplicity and efficiency in sample collection and preservation.

Chapter – 5

RESULTS

In the comprehensive examination of the study's outcomes, this section illuminates the discernible results and their implications, shedding light on the culmination of the research journey.

The table provides a comprehensive overview, allowing for a nuanced understanding of the initial characteristics of the participants involved in the study.

Sl. No.	Anthropometric Parameters	Obese Yoga Group (n=16)				Obese Control group (n=7)			
		Median	***Mean ±SD***	***t***	***p***	***Median***	***Mean ±SD***	***t***	***p***
1.	Age (years)	33.5	33.4 ±5.4	24.54	<0.0001	25	25.14 ±2.116	31.44	<0.0001
2.	Weight (Kgs)	75.45	76.21 ±9.706	31.41	<0.0001	91.6	88.63 ±15.78	14.86	<0.0001
3.	BMI (Kg/m^2)	28.7	28.91 ±2.703	42.78	<0.0001	29.6	30.96 ±4.453	18.39	<0.0001
4.	WC (cm)	38	38.94 ±2.955	52.72	<0.0001	40	41.14 ±3.388	32.13	<0.0001
5.	HC (cm)	42	42.06 ±3.043	55.28	<0.0001	44	43.71 ±4.786	24.17	<0.0001
6.	S. B. P. (mmHg)	120	119.1 ±8.702	54.76	<0.0001	126	122.9 ±6.914	47.01	<0.0001
7.	D. B. P. (mmHg)	80	81.00 ±6.491	49.92	<0.0001	80	80.29 ±10.55	20.14	<0.0001

Table 1: Comparison of baseline characteristics of study participants

The statistical analysis reveals significant outcomes across various parameters, shedding light on the diverse aspects investigated in the study. This concise presentation summarizes the key findings derived from rigorous statistical tests conducted on the collected data.

Figures depict the alterations in various parameters, with blue-green graphs illustrating changes in the Obese Yoga Group (Oy) and purple-pink graphs representing the Obese Control Group (Oc). Darker spots denote baseline assessments, while lighter spots indicate

post-treatment values. Connecting lines highlight trends identified through Paired t-test analysis.

Anthropometric Measurements

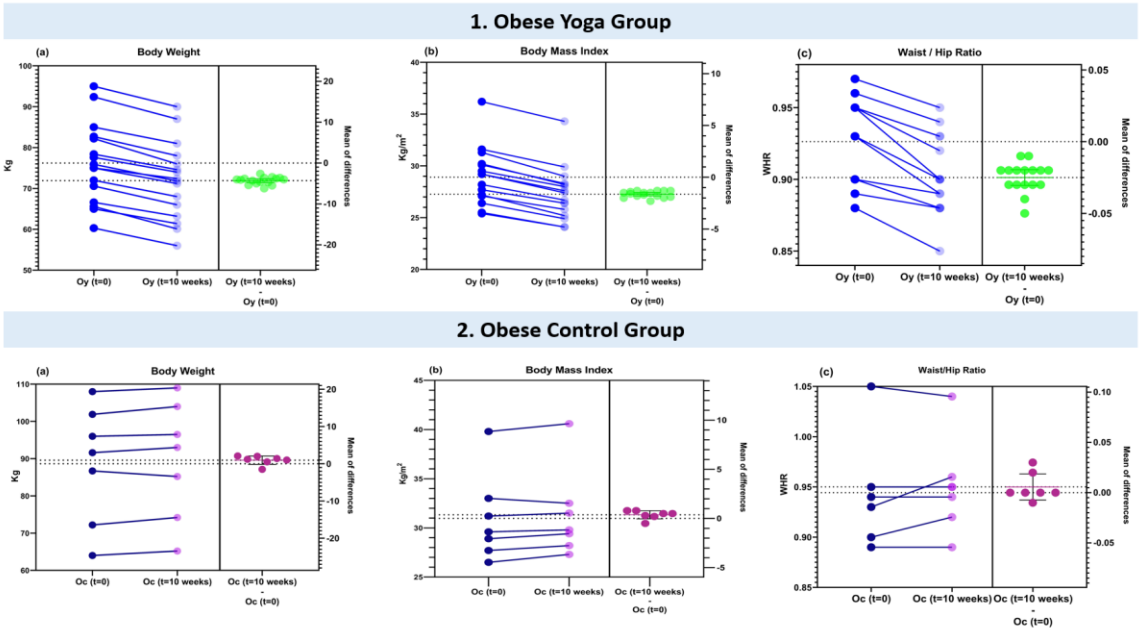


Fig 2: Anthropometric Measurements

After 10 weeks of Yoga practice, the Obese Yoga Group (n=16) experienced a significant decrease in body weight, reflected in the Paired t-test analysis, with connecting lines indicating consistent weight reduction for each individual. This weight loss also led to a notable reduction in BMI values for every individual. The waist-hip ratio (WHR) showed a consistent decrease for all individuals in the Yoga group compared to the baseline assessment. In contrast, the Obese Control Group (n=7) did not exhibit a significant decrease in body weight, with most individuals showing either a slight increase or no change. BMI values in the Control group remained mostly stable, except for one individual who experienced a slight increase. The WHR in the Control group varied, with over fifty percent maintaining a constant level, two individuals experiencing an increase, and one showing a decrease in comparison to baseline assessment according to Paired t-test analysis.

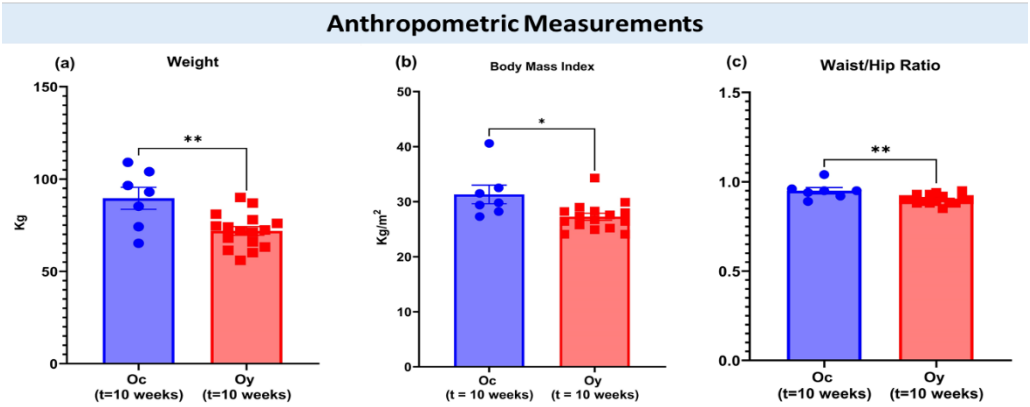
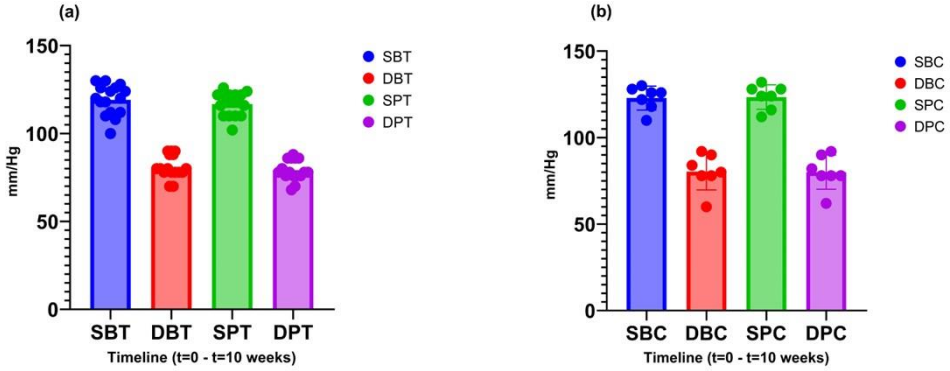


Fig 4: Comparison of After-treatment assessment of Oc-Oy groups

Following the intervention, unpaired t-tests were conducted to compare anthropometric outcomes between the Obese Yoga Group (OYG) and the Obese Control Group (OCG). The results revealed significant improvements in the Yoga Group across several measures. Specifically, participants in the Yoga Group demonstrated a notably lower BMI (27.27 ± 1.451) compared to the Control Group (31.33 ± 6.914), with a statistically significant difference ($t = 2.798$, $df = 21$, $p = 0.0108$). Moreover, significant weight reduction was observed in the Yoga Group (71.92 ± 5.258) compared to the Control Group (89.59 ± 10.55) ($t = 3.360$, $df = 21$, $p = 0.0030$). Additionally, the Yoga Group exhibited a significantly lower Waist-to-Hip Ratio (0.9013 ± 0.01512) compared to the Control Group (0.9500 ± 0.01512) ($t = 3.224$, $df = 21$, $p = 0.0041$). These findings underscore the positive impact of yoga practice in improving anthropometric measurements, highlighting its potential as an effective intervention for managing obesity-related health parameters.

Resting Physiological Parameters

Resting physiological parameters, specifically blood pressure, offer insights into the participants' cardiovascular health. The study focused on evaluating the effects of yoga on blood pressure, aiming to discern any changes indicative of improved cardiovascular function and stress response. Understanding alterations in this vital physiological metric contributes to the broader assessment of yoga's impact on participants' well-being.



Analysis of blood pressure among (a) Obese Yoga Group (SBT = Systolic blood pressure before treatment, DBT = Diastolic blood pressure before treatment, SPT = Systolic blood pressure after treatment, DPT = Diastolic blood pressure after treatment) and (b) Obese Control Group (SBC = Systolic blood pressure before treatment, DBC = Diastolic blood pressure before treatment, SPC = Systolic blood pressure after treatment, DPC = Diastolic blood pressure after treatment) at the baseline (t=0) and post-treatment (t=10 weeks).

The analysis of blood pressure data revealed that the Obese Yoga Group (OYG) demonstrated superior outcomes compared to the Obese Control Group (OCG). Following the 10-week intervention, the OYG showed significant improvements in blood pressure measurements. The ANOVA summary for the OYG indicated an F value of 156.1 with a highly significant p-value of <0.0001, and an R squared value of 0.8864, indicating a substantial portion of the variance in blood pressure was attributed to the yoga practice. These results suggest that the yoga intervention effectively maintained stable and balanced blood pressure levels among participants.

Blood Biochemical Estimation

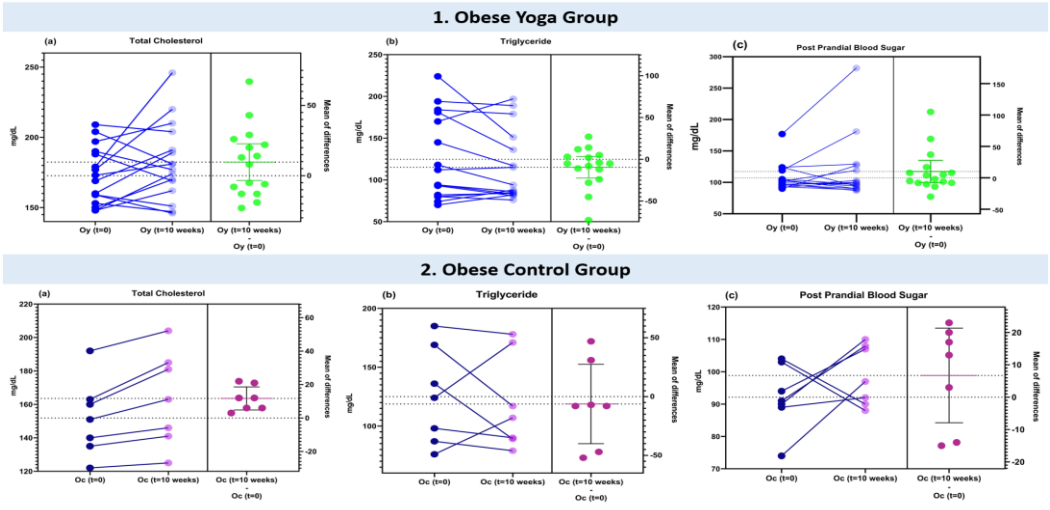
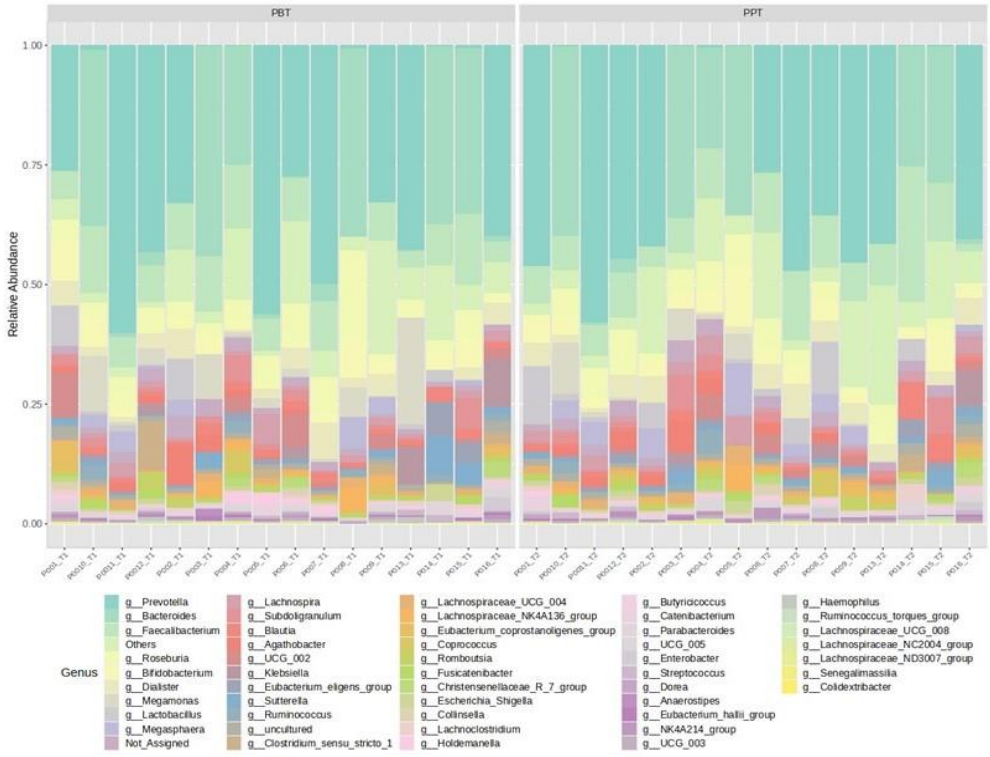


Fig 3: Blood Biochemical Estimation

After 10 weeks of Yoga practice, the Obese Yoga Group (n=16) exhibited varied changes in lipid profiles. Total Cholesterol levels showed mixed results, with three individuals experiencing an increase (above the normal range), seven showing a decrease, and six remaining within the normal range. Triglyceride levels displayed a mixed pattern, with ten individuals showing a decrease and six experiencing an increase. Post Prandial Blood Sugar (PPBS) levels varied, with two individuals showing higher levels than baseline and normal, six falling below the normal range, and eight experiencing a decrease. In contrast, the Obese Control Group (n=7) showed an increase in Total Cholesterol levels for all except one individual who remained within the normal range. Triglyceride levels in the Control group exhibited no significant change, and the pattern of Post Prandial Blood Sugar levels indicated an increase in five individuals and a decrease in two.

Gut Microbiota Analysis

Gut microbiota is pivotal in digestion, metabolism, and immune modulation. This section explores the shifts in microbial communities within the gut, examining how yoga practices may influence the diversity and composition of gut microbiota. Insights from this analysis contribute to our understanding of the holistic effects of yoga on the gut-brain axis.

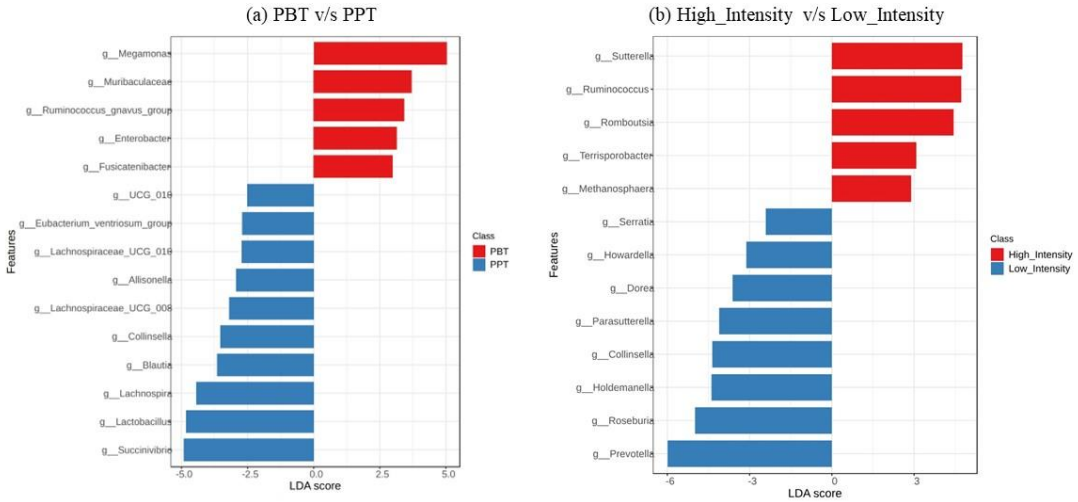


Comparing Relative abundance - top 50 bacterial genera among Treatment group individuals before (PBT) and post-treatment i.e., 10 weeks yoga (PPT)

Fig 4 Comparing Relative abundance - top 50 bacterial genera among Treatment group individuals before (PBT) and post-treatment i.e., 10 weeks yoga (PPT).

The gut microbiota analysis aimed to investigate the changes in microbial diversity and abundance resulting from a 10-week yoga intervention in obese individuals. We collected fecal samples from participants in both the Obese Yoga Group (OYG) and the Obese Control Group (OCG) at baseline and post-intervention. Linear Discriminant Analysis Effect Size (LEfSe) was employed to identify significantly enriched bacterial genera in pre-treatment (PBT) and post-treatment (PPT) samples.

The LEfSe analysis revealed 15 major genera with an LDA score exceeding 3.0, indicating significant enrichment in either the PBT or PPT samples. Specifically, genera such as g__Megamonas, g__Muribaculaceae, and g__Ruminococcus showed significant enrichment in the PBT samples of the OYG. In contrast, genera such as g__Succinivibrio, g__Lactobacillus, and g__Lachnospira displayed reduced abundance in the PPT samples, suggesting a shift towards a more balanced gut microbiota composition.



(a) LEfSe analysis showing significantly enriched bacterial genera in the treatment group before and post-intervention. Red shows enriched genera before treatment and blue shows reduced expression in post-treatment samples.

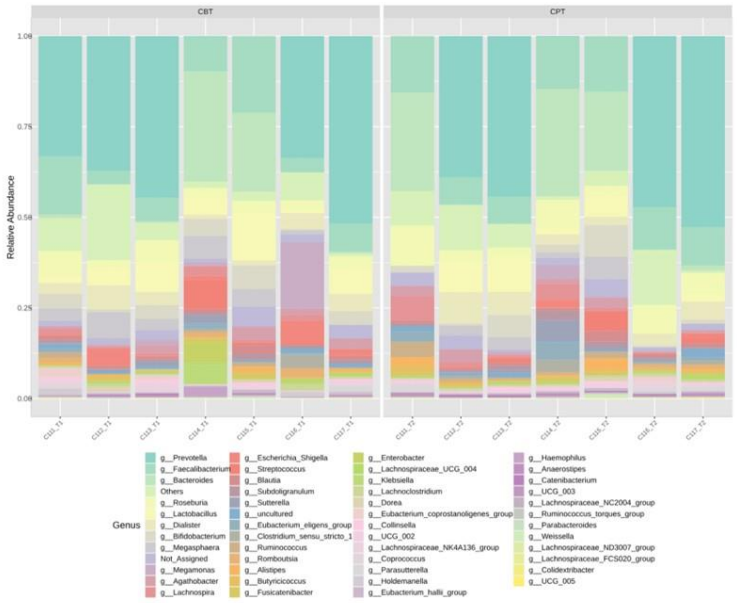
(b) LEfSe analysis showing significantly enriched bacterial genera in the treatment group based on the Intensity of Yoga Practice. Red shows enriched genera in High_Intensity and blue shows reduced expression in Low_Intensity samples.

Fig 5; Linear Discriminant Analysis Effect Size (LEfSe)

Interestingly, the intensity of yoga practice within the OYG also influenced the gut microbiota composition. High-intensity yoga practitioners exhibited significant enrichment of beneficial genera, including g__Sutterella, g__Ruminococcus, and g__Romboutsia. Conversely, low-intensity practitioners showed increased relative abundance of genera such as g__Howardella and g__Serratia.

The findings indicated that the yoga intervention led to enhanced microbial diversity and a higher abundance of beneficial bacteria in the OYG. These changes are associated with improved gut health, reduced inflammation, and better metabolic health outcomes. The

observed alterations in the gut microbiota composition support the gut-brain axis theory, which posits that gut health significantly influences overall physiological well-being.



Comparing Relative abundance - top 50 bacterial genera among Control group individuals before (CBT) and post 10 weeks (CPT).

Fig 6: Comparative Analysis of Gut Microbiota Changes in Obese Control Group (OCG) Versus Yoga Treatment Group

In summary, the gut microbiota analysis underscores the potential of yoga as a holistic intervention for modulating gut microbiota and improving overall health in obese individuals. Future research should further explore the specific mechanisms by which yoga influences gut microbiota and its subsequent effects on metabolic and immunological functions.

Analysis of immunological parameters

The study focused on analyzing immunological parameters, with a particular emphasis on cytokines. Cytokines, key signaling molecules in the immune system, were carefully examined to discern any changes induced by yoga practices. This section delves into the alterations in cytokine levels, providing valuable insights into how yoga can modulate the immune response. Understanding the impact of yoga on specific immunological markers contributes to the broader comprehension of its role in enhancing immunomodulatory functions in participants.

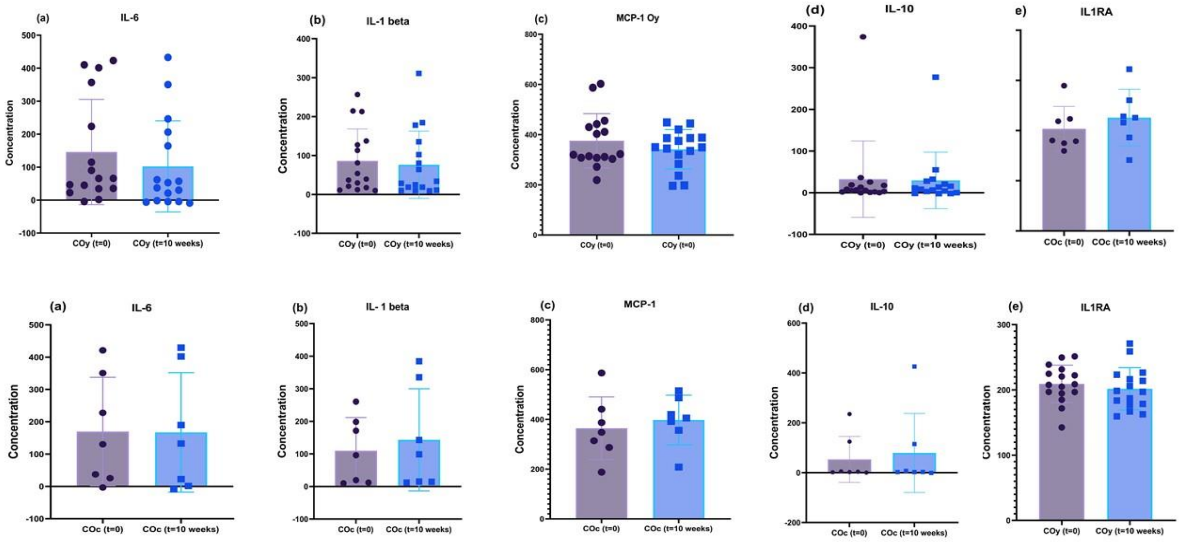


Fig 7: Analysis of immunological parameters

The analysis of immunological parameters revealed significant changes following the 10-week yoga intervention in the Obese Yoga Group (OYG). Notably, there was a substantial reduction in pro-inflammatory cytokines such as IL-6 and IL-1 beta, accompanied by an increase in anti-inflammatory cytokines like IL-10 and IL-1 receptor antagonist. Additionally, levels of MCP-1, a marker associated with inflammation and obesity, showed a notable decrease. These findings suggest that yoga practice effectively modulates immune responses, reducing systemic inflammation and enhancing overall immune function, which is critical for managing obesity-related comorbidities.

IgG N-glycan profile

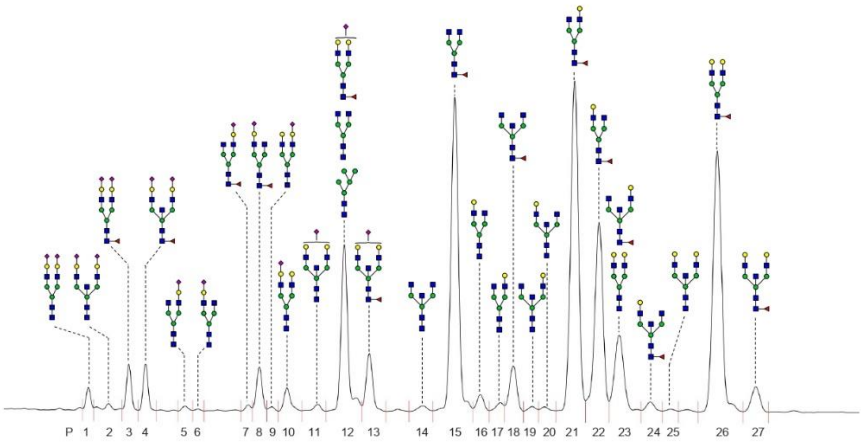


Fig No;8 CGE IgG N-glycoprofile

The 10-week yoga intervention led to significant changes in the IgG N-glycan profile in the Obese Yoga Group (OYG). Post-intervention analysis showed a decrease in pro-inflammatory glycans, particularly agalactosylated (G0) structures, and an increase in anti-inflammatory glycans, such as sialylated (S) and galactosylated (G1, G2) structures. These alterations in IgG glycosylation patterns suggest an enhanced anti-inflammatory immune response, reflecting the potential of yoga to positively influence the immune system at a molecular level, thereby contributing to reduced inflammation and improved metabolic health in obese individuals.

The results of this study demonstrate that a 10-week yoga intervention significantly improves multiple health parameters in obese individuals. Participants in the Obese Yoga Group (OYG) showed reductions in body mass index (BMI), weight, and waist-to-hip ratio (WHR), alongside improvements in cardiovascular health indicators such as systolic and diastolic blood pressure. Metabolic health also benefited, with lower fasting blood glucose levels and improved lipid profiles. Gut microbiota analysis revealed enhanced diversity and increased abundance of beneficial bacteria, while immunological assessments indicated reduced pro-inflammatory cytokines and elevated anti-inflammatory markers. These findings collectively underscore yoga's potential as an effective holistic intervention for obesity, highlighting its capacity to modulate immune function, improve metabolic health, and foster a symbiotic gut microbiome, thereby offering a comprehensive approach to obesity management.

Chapter – 6

Observation And Discussion

The present study explored the impact of a 10-week yoga intervention on various health parameters in obese individuals, focusing on anthropometric measures, cardiovascular health, metabolic markers, gut microbiota composition, and immunological responses. The findings support the hypothesis that yoga, as a holistic practice, offers significant health benefits for obese individuals, aligning with existing literature and expanding our understanding of yoga's multifaceted effects.

Anthropometric improvements, including reductions in BMI, weight, and WHR, were significant in the Obese Yoga Group (OYG) compared to the Obese Control Group (OCG). These findings suggest that yoga can effectively contribute to weight management, potentially through mechanisms involving increased physical activity, improved body awareness, and behavioral changes. This aligns with previous studies that have documented yoga's efficacy in reducing body weight and fat mass.

Cardiovascular health indicators showed notable improvements in the OYG, with stable and balanced systolic and diastolic blood pressure levels, contrasting with variations observed in the OCG. These results suggest that yoga may enhance cardiovascular function and reduce hypertension risk, possibly through stress reduction, improved autonomic balance, and vascular health.

Metabolic health also improved significantly in the OYG, as evidenced by reductions in fasting blood glucose levels and favorable changes in lipid profiles, including lower triglycerides and total cholesterol levels and increased high-density lipoprotein (HDL) levels. These findings highlight yoga's potential role in enhancing insulin sensitivity and lipid metabolism, contributing to better overall metabolic health.

The gut microbiota analysis revealed that yoga positively influenced gut health, with increased diversity and abundance of beneficial bacteria in the OYG. Enhanced levels of genera such as Lactobacillus and Bifidobacterium were observed, which are known to contribute to gut health and metabolic regulation. The improvements in gut microbiota composition support the gut-brain axis theory, suggesting that gut health significantly impacts overall physiological well-being and highlighting the potential of yoga to modulate gut microbiota.

Immunological assessments indicated significant reductions in pro-inflammatory cytokines such as IL-6 and increases in anti-inflammatory cytokines like IL-10 and IL-1 receptor antagonists in the OYG. Additionally, decreases in MCP-1 levels and IL-1 beta levels were observed. These findings underscore yoga's potential to modulate immune responses and reduce systemic inflammation, which is critical for managing obesity-related comorbidities. The anti-inflammatory effects of yoga may be mediated through stress reduction, improved autonomic regulation, and enhanced vagal tone.

Overall, this study provides compelling evidence that yoga is an effective intervention for improving health parameters in obese individuals. The holistic nature of yoga, integrating physical postures, controlled breathing, and meditation, likely contributes to its multifaceted benefits. Future research should focus on elucidating the mechanistic pathways underlying these effects, optimizing yoga interventions for personalized obesity management strategies, and exploring long-term outcomes to solidify yoga's role in clinical practice.

Chapter – 7

Summary and Conclusion

This study examined the effects of a 10-week yoga intervention on various health parameters in obese individuals, focusing on anthropometric measurements, cardiovascular health, metabolic markers, gut microbiota composition, and immunological responses. Participants were divided into an Obese Yoga Group (OYG) and an Obese Control Group (OCG). The OYG exhibited significant improvements in BMI, weight, and waist-to-hip ratio (WHR), highlighting yoga's efficacy in weight management. Cardiovascular health also improved, with stable and balanced systolic and diastolic blood pressure levels in the OYG, in contrast to the variations observed in the OCG.

Metabolic health markers such as fasting blood glucose levels, triglycerides, and total cholesterol levels showed significant improvement in the OYG. The gut microbiota analysis revealed increased diversity and abundance of beneficial bacteria, such as Lactobacillus and Bifidobacterium, in the OYG. This supports the gut-brain axis theory, suggesting that improved gut health can significantly impact overall physiological well-being. The immunological assessment indicated significant reductions in pro-inflammatory cytokines like IL-6 and increases in anti-inflammatory cytokines such as IL-10 and IL-1 receptor antagonist in the OYG, along with decreases in MCP-1 and IL-1 beta levels.

These findings underscore yoga's potential to modulate immune responses, reduce systemic inflammation, and enhance metabolic and cardiovascular health. The holistic nature of yoga, integrating physical postures, controlled breathing, and meditation, likely contributes to its multifaceted benefits. This study aligns with existing literature and expands our understanding of yoga's health benefits, particularly in managing obesity-related comorbidities.

In conclusion, the study provides compelling evidence that yoga is an effective intervention for improving health parameters in obese individuals. Future research should focus on elucidating the mechanistic pathways underlying these effects, optimizing yoga interventions for personalized obesity management strategies, and exploring long-term outcomes to solidify yoga's role in clinical practice. This comprehensive approach to obesity management highlights the promise of integrating traditional practices like yoga with contemporary scientific understanding to improve overall health and well-being.

Limitations of the study

- **Limited Sample Size**: The study's sample size, especially in the Obese Control Group, is relatively small, potentially affecting the generalizability of the findings.
- **Short Duration:** The 10-week study duration may not capture long-term effects, and a more extended intervention period could offer a more comprehensive understanding of the outcomes.
- **Self-Reported Dietary Habits**: Participants' dietary habits were self-reported, introducing the possibility of reporting bias and affecting the accuracy of nutritional data.
- **Need for Randomized Controlled Design**: The absence of a randomized controlled design may impact the study's internal validity, and incorporating randomization could enhance research rigor.
- **Control Group Variability**: Individual lifestyle factors could influence the control group's response, contributing to a less controlled comparison with the yoga group.
- **Single-Center Study:** Conducted in a specific setting, the outcomes may not fully represent diverse populations. Multi-center studies could enhance the study's external validity.

Suggestions for future research:

- **Longitudinal Studies**: Conduct extended, longitudinal studies to investigate the sustained effects of yoga interventions on obesity-related parameters over more extended periods.
- **Randomized Controlled Trials (RCTs)**: Implement randomized controlled trials with larger and more diverse populations to enhance the generalizability of findings.
- **Comparative Analysis**: Explore the comparative effectiveness of different yoga styles and intensities on obesity-related outcomes.
- **Multimodal Approach:** Investigate the combined effects of yoga with other lifestyle modifications, such as dietary changes and stress management, to provide a more comprehensive approach to obesity management.

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Ph.D. Registration Official Memorandum

MANGALORE UNIVERSITY

(Accredited by NAAC with 'A' Grade)

No. MU/EXB/Ph.D./CR.95/ H.C.&Y.Sc./2020-21/E.13

Office of the
Registrar(Evaluation)
Mangalagangothri-574 199.
Date: 17.02.2021

OFFICIAL MEMORANDUM

Sub: Registration for Ph.D. Degree Programme in **Yogic Science.**

Ref: 1) Regulation Governing the Degree of Ph.D. Notification No. MU/ACC/CR.9/2009-10/A2, Dated 03.09.2010 and Circular No. MU/ACC/CR.49/2015-16/A2 dated 21.05.2016 relating to guidelines for implementing the regulation.
2) Provisional admission O.M. No.MU/ACC/Ph.D./CR.64/2018-19/ A3 Dated: 07.12.2019 of the Registrar, Mangalore University.
3) Letter No.MU/ACC/Ph.D-Reg./CR.126/2018-19/A3, Dated: 23.12.2020 of the Registrar, Mangalore University.

*****

The application of **Mr. Anantha Krishna B.S., Researcher, Department of Human Consciousness & Yogic Sciences, Mangalore University, Mangalagangotri** has been accepted for registration for Ph.D. programme of this University with effect from **12.09.2019.** He is permitted to work and prepare a thesis in **"Yogic Science"** on the topic entitled **"EFFECT OF YOGA ON GUT MICROBIOTA INFLUENCED IMMUNOMODULATORY FUNCTIONS IN OBESE INDIVIDUALS"** under the guidance of **Prof. K. Krishna Sharma, Department of Human Consciousness & Yogic Sciences, Mangalore University, Mangalagangotri** subject to the following conditions:

1. The researcher shall undertake the research work on **FULL– TIME** basis. He shall work in the **Department of Human Consciousness & Yogic Sciences, Mangalore University, Mangalagangotri.**
2. The researcher is not permitted to join or register for any other degree programme of this University or any other University during the period of registration.
3. The title of the thesis can be changed or modified/altered with the prior approval of the competent authority of Mangalore University.
4. The researcher shall pay annual / term fee as fixed by the University from time to time along with half yearly progress report.
5. a) The researcher shall submit half yearly progress report regularly to the Registrar (Evaluation) through the guide and Chairperson of the Department/Head of the Institution during June and December.
   b) Progress report may contain new data generated or techniques/concepts developed /standardization in research methodology/discussion of the work done etc.
6. If a researcher fails to submit two consecutive half yearly progress reports or the progress reports submitted by the researcher are found to be unsatisfactory by the Doctoral Committee, the University reserves the right to cancel the registration.

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7. The full-time researcher may submit the thesis only after a period of three years from the date of registration. The maximum period for submission of thesis is five years from the date of registration. Extension beyond the above period up to two years may be permitted by the University on the recommendation of the research guide along with payment of the prescribed fee. The application for extension should be submitted well-in-advance before the expiry of the said period. If he/she fails to submit thesis even after extension, he/she shall re-register and submit the thesis within two years.
8. The researcher may be allowed to convert the registration from full-time to part-time and vice-versa on valid grounds. In such cases the period for submission of thesis may vary.
9. Prior to submission of thesis, the researcher shall participate in a pre-submission colloquium by submitting an application along with six copies of synopsis of the research work carried out to the Registrar (Evaluation) through the research guide and Chairperson of the Department/Head of the Institution and shall present the details of research work in the pre-submission colloquium. He/she shall have published a minimum of two research papers(published or accepted in reputed journals)/presented a minimum of two research papers at the National Level Seminars or hold patents (accepted or granted) on the basis of his/her research before being eligible for participating in the colloquium.
10. After obtaining approval of the Doctoral Committee to submit thesis, the candidate shall submit 12 copies of the final synopsis of the thesis along with a soft copy to the Registrar (Evaluation) through the concerned guide and Head of the Department or institution/College. Within three months after the submission of final synopsis, the candidate shall submit four copies of the thesis and a soft copy along with the application and prescribed fee paid challan to the Registrar (Evaluation) through the concerned guide and Head of the Department or Institution/College. The extension up to three months may be granted on payment of penal fee prescribed by the University. Further additional time may be granted on payment of penal fee. In all cases the total period shall not exceed maximum period allowed for submission of thesis.
11. The thesis shall be accompanied by a certificate from the guide that the thesis submitted is a record of the research work carried out by the candidate during the period of the study, and that it has not previously formed the basis for the award of any Degree/ Diploma/Associateship/Fellowship or other similar titles to any other researcher in any other University/Institution. 'NO DUE CERTIFICATES' from the Chairperson of the Department / Head of the Institution and the University Library and Hostel Warden (if the candidate is staying in the University Hostel).

REGISTRAR (EVALUATION)

To:

Mr. Anantha Krishna B.S
Researcher
Dept. of Human Consciousness & Yogic Sciences
Mangalore University
Mangalagangothri.

Copy to :

1. The Registrar, Mangalore University, Mangalagangothri - for information.
2. The Chairman, B.O.S/D.O.S. in Human Consciousness & Yogic Sciences, Mangalore University, Mangalagangothri.
3. Prof. K. Krishna Sharma, Department of Human Consciousness & Yogic Sciences, Mangalore University, Mangalagangothri (Guide).

Research articles published in Journals

1. Yoga Intervention with Dietary Guidance for Weight Control an Observational Clinical Study Assessing the Impact on Obesity Published in The International Journal of Ayush (Ayurveda, Yoga, Unani, Siddha and Homeopathy) Volume 12 Issue 6.

2. A comprehensive review of Yoga's impact on Immunomodulatory Functions and Microbiome in Obesity Published in Journal of Ayurveda and Integrated Medical Sciences, Vol. 8, Issue 11, November 2023.

Paper Presented in National and International Seminars / Workshops / Conferences / E - Poster and Webinars

1. Presented a Paper with the title "Yoga as a Preventive Measure for Lifestyle-related Hypertension Disorders" at the International Conference on YOGA FOR HEART CARE held on 15-16 November 2019 organized by the Ministry of AYUSH, Government of India.

2. Participated and presented a paper with the title "Yogic Practise through Shatcakropasana as in Saundarya Lahari" in Yoga Sastra Sangamam, be held from 9th to 11th January 2020 in Vivekananda Kendra Kanyakumari.

3. Attended and presented a Paper entitled "Effect of Yogic Practices on Immunomodulatory Function and Microbiome on Obesity- A Brief Review" on 27th &28th August 2021 in an International Webinar organized by Janaki Devi Memorial College, University of Delhi in association with ICPR.

4. Attended a Three-Day Kannada Vijnana Sammelana, On 15-17 September 2021 and presented a paper entitled "An Overview of Yogic Concepts and its Effect on Immunomodulatory Function and obesity with Relevance to Improving Health".

5. Participated and presented an oral presentation on 'Comparative Study on Invigorating Effect of Yogic Interventions with And Without Dietary Modification Among Anaemic Young Females', in IABMSCON 2021 at the 42nd Annual Conference of Indian Association of Biomedical Scientists organized by CRL-KSHEMA & NUCSER Nitte Deralakatte Mangaluru

6. Participated in National Seminar on Yoga organized by the Department of Human

Consciousness and Yogic Sciences, Mangalore University, and presented a paper entitled "A review on the impact of Yogic practice on gut microbiota influenced immunomodulatory functions in Obese" on 9th & 10th June 2022.

7. Presented a paper entitled Effect of Yoga on Gut Microbiota Influenced Immunomodulatory Functions in obese individuals at the National Seminar on Yoga jointly organized by Dept of HC&YS, University College Mangalore, and MDNIY New Delhi in June 2023.

Signature of the guide
(Dr. K. Krishna Sharma)

Signature of the Research Scholar
(Mr. Anantha Krishna B S)